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International linkages, local externalities, innovation and productivity

A structural model of Italian manufacturing firms

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Roberto Antonietti[1] and Giulio Cainelli[2]

Abstract
Using a large sample of Italian manufacturing firms, in this paper we estimate a structural model of research, innovation, productivity and export performance augmented to take account for the role played by local externalities. This model, which is an "enlarged" version of Crepon, Duguet and Mairesse (1998) model, comprises four main equations. The first identifies the factors underlying the intensity of Research and Development (R&D) investments; the second links R&D capital to innovation output; the third focuses on Total Factor Productivity (TFP) as determined by innovation; the fourth relates export performance to TFP. Our estimates show the significant role played by local externalities in these processes. In particular, related variety and urbanization positively affect the creation of new ideas through R&D, while specialization impacts on TFP to complement innovation output. Finally, urbanization economies support TFP in driving firms' export performance.

Keywords: export, innovation, productivity, R&D, spatial agglomeration

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1. Introduction

Since the 1990s there has been great emphasis in the literature on the role of spatial agglomeration, technological innovation and internationalisation as the main drivers of the economic performance of manufacturing firms. However, while the positive role of innovative activities in enhancing productivity growth in manufacturing and service firms is now considered a robust stylized fact (Griffith *et al.*, 2004; Griliches and Mairesse 1985, 1995; Hall and Mairesse 1995; Harhoff 1998; Wakelin 2001; Wang and Tsai 2003; Parisi *et al.*, 2006; Cainelli *et al.*, 2006) the sign and the intensity of spatial agglomeration, and thus local knowledge spillovers effects on economic performance, are still a puzzling and unresolved question.
Starting with the seminal papers of Glaeser *et al.* (1992) and Henderson *et al.* (1995), the relationships between local knowledge spillovers, such as Marshall-Arrow-Romer

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(MAR) externalities, Porter and Jacobs externalities, and economic performance have been extensively investigated at both industry and firm levels (De Lucio *et al.*, 2002; Henderson, 2003; Cingano and Schivardi, 2003; Martin *et al.*, 2008). But, these studies do not reach a definite, clear-cut conclusion about the role of these variables.

In addition to this literature, a line of research, linked to the new theory of international trade, is showing that economic performance, measured as firms' Total Factor Productivity (TFP) or labour productivity, can affect in turn the export propensity of firms and their internalisation strategies, more generally. In other words, most works in this strand show that more productive firms tend to have higher export propensities (Wagner, 2005) or, more generally, that firms with different levels of productivity – the main source of firm heterogeneity – tend to be engaged in different modes of internationalization. According to this literature, this is because internationalization is characterized by different levels of sunk costs: i.e., firms need to acquire information on foreign market, establish distribution channels, and so on. This stream of literature, therefore, finds that exporters benefit from larger and significant performance premia relative to non-exporting firms, and thus identifies a causal positive relationship between productivity and exports.

All these studies suggest the presence of a "complex" dynamic relationship between gglomeration, innovation and internationalization, which passes through firm productivity. Underling these contributions is the idea that agglomeration and innovation may affect productivity, which, in turn, may have a role in explaining firms' export performance.

In spite of the relevance of these phenomena, the number of empirical studies that deal with these complex relationships is limited. This paper is an attempt to filling this gap. In particular, we model these complex and dynamic structural relationships, estimating an "enlarged" version of Crepon, Duguet and Mairesse (CDM hereafter) model, developed to summarize the complex process "that goes from the firm decision to engage in research activities to the use of innovations in its production activities" (Crepon *et al.*, 1998, p.116).

We modify this model in two ways. First, to the three equations characterizing the "traditional" CDM model, i.e., the "research activity" equation linking Research and Development (R&D) to its main determinants, the "innovation" equation relating research to innovation output, and the "productivity" equation relating innovation output to TFP, we add a fourth that refers to "exports". This equation emphasizes the empirical link with firm heterogeneity – being the TFP the main source of – in determining the performance of firms on foreign markets.

Second, we use this four equation recursive model to empirically test the role played by different forms of agglomeration economies in each stage of the firm process from the decision to engage in R&D to the decision to export. We introduce into each of the four equations a set of measures for local knowledge spillovers. We consider three specific forms of local externalities: (i) localization economies (also known as MAR economies), arising from the spatial concentration of firms belonging to the same industry; (ii) Jacobs's externalities, which are spurred by the variety and diversity of geographically proximate industries, and capture knowledge spillovers from the cross-fertilization of ideas by firms operating in related or unrelated-sectors (Frenken *et al.*, 2007; Boschma and Iammarino, 2009); and (iii) urbanization economies, which mainly involves information spillovers as local public goods, external to both firms and industry, and which are related to the size of the market and the density of the urban area in which the firm is located (Frenken *et al.*, 2007; Chevassus-Lozza and Galliano, 2008).

Controlling for sample selection and simultaneity, we estimate this recursive four equations system using a large sample of over 700 Italian manufacturing firms. Data, for the period 1998-2003, are drawn from merging information from the VII, VIII and IX Survey on Manufacturing Firms conducted by Unicredit-Capitalia (formerly *Mediocredito Centrale*) with 1991 census data on manufacturing and service industries provided by the National Statistical Institute (ISTAT).
We measure research intensity empirically by real investment in R&D per employee. Since our sample includes firms that do not engage in R&D, we account for possible sample selection bias by using the Heckman (1976, 1979) two-step procedure: in the first stage, estimating firm propensity to invest in R&D, and, in the second stage, estimating the determinants of R&D intensity. Innovation output is measured through firm propensity to introduce a new product or new process in the three years 2001-2003.
We also examine the probability of a new product (product innovation) or a new process (process innovation). Productivity is measured by both TFP and value added per employee. In order to compute TFP we assume a standard, two-input Cobb-Douglas production function with output measured as deflated value added at each three-digit sector level. To avoid simultaneity, we estimate TFP using the Levinsohn and Petrin (2003) semi-parametric approach, where we use a composite index of materials and services in order to control for unobservables. Finally, we measure export performance (i) as the propensity to export; (ii) as the share of export sales; and (iii) as the number of macro-areas in which firms exported in 2003.
The main contribution of this paper to the literature is that unlike other empirical studies, we do not rely on a "reduced form" rather estimate a structural model that allows us to identify which forms of spatial agglomeration affect innovation, productivity and export performance, and at what level.
The paper is organized as follows. In Section 2 we briefly review the related literature. In Section 3 we describe the dataset, present the modelling strategy and discuss the main empirical results. Section 4 concludes the work.

2. Related literature

2.1. The role of technological innovations on productivity

Innovation and technological change are important factors in analyses of the determinants of long-term economic growth, and in firm or industry level investigations of the relationship between innovation and economic performance. The first analysis of innovation and technological change was conducted by Solow (1957). In this and subsequent contributions based on a theoretical framework originating in the aggregate production function, Solow tried to identify technical progress in the "residual" component of economic growth, which cannot be explained by the contribution of production factors such as labour and capital. This so-called "growth accounting" approach emphasize the relevance of technological change as a key factor explaining the aggregate productivity of an economic system.
Within an analytical framework based on production functions, most analyses at industry or firm level confirm the importance of investment in R&D, and of innovative activities more generally, in determining firms' competitive advantage. The works of Griffith *et al.* (2004), Griliches and Mairesse (1985, 1995), Hall and Mairesse (1995), Harhoff (1998), Parisi *et al.* (2006), Wakelin (2001), and Wang and Tsai (2003) are examples of such studies. They generally find a positive effect of technological innovations on productivity growth. An alternative approach to analysing technological change is based on the

fundamental contributions of Schumpeter (1939, 1943). Within this line of research, technological change is interpreted as a process of creative destruction. Although neo-Schumpeterian approaches such as the evolutionary theories of economic and technological change differ from the mainstream in terms of their theoretical framework, they agree about the impact of technological innovation on aggregate and firm-level performance (Antonelli 2003; Dosi 1988; Malerba and Orsenigo 1995; Metcalfe 1997, 1998).

2.2 The role of spatial agglomeration on productivity

Another body of works focuses on the positive effects on productivity of spatial agglomeration. This stream of literature originated in the early 1990s when the relationships between spatial agglomeration, knowledge spillovers, and economic growth at the urban level were extensively investigated (Glaeser *et al.*, 1992; Henderson *et al.*, 1995). Using a cross-section of US cities, Glaeser *et al.* (1992) analyse the impact of three different forms of local knowledge spillovers – MAR, Porter and Jacobs externalities – on subsequent urban employment growth. Glaeser *et al.* show that localization economies or MAR economies, which arise from the spatial concentration of firms belonging to the same industry, and are captured by specialization indicators, have a negative impact on urban economic growth, while urbanization (or Jacobs) economies, spurred by the variety and diversity of geographically proximate industries, positively affect the subsequent growth of a metropolitan area.

Using a similar empirical framework, Henderson *et al.* (1995) find that localization plays a positive role in mature capital-goods sectors, while productive structure differentiation (variety), which should generate the cross-fertilization of ideas between different industries, has a positive impact only in the case of high-tech industries. Using French data, Combes (2000) also finds a rather negative impact of specialization on employment growth in both industry and service sectors. Finally, Forni and Paba (2002), using information on a cross section of 995 Italian LLS for the period 1971-1991 find that in most cases specialization and variety positively affect growth, but that the effect of variety is different for each industry. They note also that, consistent with Marshall (1920), in order to capture the spillover-generating process a size effect needs to be added to the specialization effect.

Glaeser *et al.*'s (1992) approach has been replicated in the contexts of different countries in order to provide further evidence on these issues. However, the various results obtained from empirical research in this field are controversial and currently there is not a unique model that explains the link between economic performance measured by employment growth, and the structure of the local economy. In particular, some studies referring to the Italian case, find that specialization has a negative impact on local growth, while diversity plays a positive role (see, among others, Cainelli and Leoncini, 1999; Cunat and Peri, 2001; Usai and Paci, 2003; Paci and Usai, 2006; Mameli *et al.*, 2007).

This empirical literature has been extended by several studies that analyse the impact of measures of agglomeration economies on both employment growth (as in the original body of literature referred to), and productivity or firms' TFP growth (De Lucio *et al.*, 2002; Henderson, 2003; Cingano and Schivardi, 2003; Martin *et al.*, 2008). The findings from this new strand of empirical research are also rather puzzling.

For example, De Lucio *et al.* (2002) investigate the relationship between labour productivity and spatial agglomeration at the level of the 50 Spanish provinces for the period 1978-1992, and find that variety plays a role in labour productivity growth, and

also find a U-shaped effect for specialization. According to their results, low levels of specialization reduce productivity growth, and high levels foster it.
Cingano and Schivardi (2003), on the other hand, use firm-level based TFP indicators to show that specialization, calculated at the level of the 784 Italian LLSs, has a positive impact on firm productivity growth, but that variety has no significant effect. However, taking local employment growth as the dependent variable, Cingano and Schivardi (2003) show that the specialization effect is reversed and becomes negative, while variety has a significant and positive impact on employment growth, thus confirming Glaeser *et al.*'s results.
Henderson (2003), using the US Census Bureau Longitudinal Research Database (LRD) shows that localization economies have strong positive effects on productivity at plant level in high-tech, but not in mechanical industries; he also finds little evidence of urbanization economies.
Martin *et al.* (2008), using French individual firm data from 1996 to 2004, find no significant effect of spatial agglomeration on firm productivity. More precisely, they find that French firms benefit from localization, but not from urbanization economies, but that benefits from industrial clustering – even though highly significant from a statistical point of view – are quite modest in terms of magnitude.
Finally, Boschma and Iammarino (2009) estimate the impact of agglomeration economies on regional economic growth, using export and import data for Italian provinces for the period 1995-2003. They find that forms of related-variety affect regional growth. Their main result is that local systems endowed with sectors that are complementary in terms of shared competences (i.e. with related-variety) perform better[3].

2.3. The role of productivity and agglomeration on export

Another relationship fundamental to our analysis is the link between productivity and exports. In fact, most empirical studies show that more productive firms tend to have a higher propensity for export (Wagner, 2005). In other words, these studies find that exporters benefit from larger and more significant performance premia relative to non-exporting firms. Two different hypotheses on the relationship between firm performance and export status are proposed in this literature (Castellani *et al.*, 2009). The first assumes that the presence of sunk costs, such as transport costs or expenses related to establishing and developing distribution channels, induces self-selection of the more productive firms (Roberts and Tybout, 1997; Bernard and Jensen, 1999). The second hypothesis underlines that firms can become more efficient after they start exporting through

[3] There is yet another body of work that focuses on the positive effects on productivity of spatial agglomeration. This includes studies of Marshallian industrial districts. Starting with Becattini's "re-discovery" in the late 1970s of this analytical category of Marshallian thought (Becattini 1989) and continued in later works (Langlois and Robertson 1995; Best 1990; Boschma and Lambooy 2002; Boschma and ter Wal 2007; Brusco 1982; Brusco *et al.* 1996; Gordon and McCann 2001, 2005; Iammarino and McCann 2006), the industrial district achieved wide notoriety as a specific type of industrial organization, within which long-term informal links among firms generate agglomeration economies, and, more generally, Marshallian externalities which take the place of scale economies internal to individual firms. Alongside this theoretical revisiting of the Marshallian district concept, a new body of empirical literature emerged. These works attempt to establish the presence of a "district effect"; that is, they try to identify empirically the agglomerative benefits that firms derive from membership in one of these productive structures. Following Signorini's (1994) contribution, research in this field (see for example Bagella and Becchetti 2000; Fabiani *et al.* 1999) show that firms in industrial districts do indeed benefit from agglomeration advantages; that is, they enjoy a "district effect." These results were derived from different econometric specifications and different data sets. However, the results on the positive effects of agglomeration on firm performance are unanimous.

learning or economies of scale effects (Clerides *et al.*, 1998). The empirical literature tends to support the first hypothesis, finding the post-entry mechanisms less relevant.
The empirical relationship between firm economic performance and export has given rise to new theoretical models that try to account for these phenomena (Bernard and Jensen, 2004; Melitz, 2003). The basic ideas behind them is that firms with different levels of productivity – the main source of firm heterogeneity – generally will be engaged in different modes of internationalization which are characterized by different sunk costs. In other words, these models assume that "servicing a foreign market entails an entry (sunk) cost, due to the fact that, for example, firms need to acquire information on the foreign market, establish distribution channels and find the appropriate suppliers of goods and services" (Castellani and Zanfei, 2007, p. 4). In this sense, these "new international trade" theories are able to link firm productivity to export performance and to internationalization modes more generally (Bernard and Jensen, 1995 and 1999; Melitz, 2003).
Finally, we would underline that most studies acknowledge the role played by spatial agglomeration (Bagella and Becchetti, 2000; Becchetti and Rossi, 2000) in export activities. For example, Becchetti and Rossi (2000), based on a sample of over 3,800 manufacturing firms drawn from the Mediocredito Centrale database for the period 1989-1991 show that spatial agglomeration, captured by localization within the boundary of an industrial district, increases average export intensity by 4 percentage points. This evidence is tested using econometric methods, which confirm the positive effects of geographical agglomeration on export intensity.
This relationship is further confirmed by more recent evidence showing that export intensity in a sample of Italian manufacturing firms tends to be higher for firms in industrial clusters compared to "isolated" firms (Banca Intesa, 2008).
Export is not the only strategy adopted by firms to achieve international expansion. Others include foreign direct investment (FDI) and a continuum of intermediate forms of internationalization such as joint ventures, trade and production licensing, sub-contracting, etc. However, most studies and reports suggest that small and medium sized firms located in agglomerated areas tend not to adopt these more complex internationalization strategies due to various technological, informative and financial constraints. Thus, our choice to focus on export is supported by the evidence in the literature and is consistent with the specific features of the Italian manufacturing system.

3. The empirical investigation

3.1. The dataset

The dataset we use in our empirical investigation consists of a sample of Italian manufacturing firms drawn from the VIII and IX waves of the Survey on Manufacturing Firms (*Indagine sulle Imprese Manifatturiere*) provided by Unicredit-Capitalia (formerly *Mediocredito Centrale*), which covers the period 1998-2003. Interviews have been conducted respectively in 2001 and 2004 for the two surveys with all firms with more than 500 employees and over a representative sample with more than 11 and less than 500 employees, stratified by geographical area, industry and employment size. The master datasets, one referring to 1998-2000 and the other to 2001-2003, gather information on 4.680 and 4.289 firms respectively.
We cleaned the data for missing observations, inconsistencies and outliers, and thus achieved a balanced sample of 715 firms, whose distributions are presented Tables 1, 2 and 3.

Table 1 – Sample distribution by size, area and Pavitt's sectors

Size	**1998-2000**	**2001-2003**	**1998-2003**
11-20	39.94	22.15	32.45
21-50	37.14	29.54	35.66
51-250	16.15	36.93	23.92
251-500	3.87	5.27	4.34
> 500	2.91	6.11	3.64
Area			
North West	37.54	35.91	41.54
North East	27.44	30.12	29.51
Centre	20.62	17.65	18.04
South	14.40	16.32	10.91
Pavitt			
Supplier dominated	52.22	50.71	48.81
Scale intensive	18.14	17.42	17.34
Specialized suppliers	24.34	26.92	29.79
Science based	5.30	3.99	4.06
N. obs.	**4.680**	**4.289**	**715**

Table 2 – Sample distribution by regions

Region	**1998-2000**	**2001-2003**	**1998-2003**
Abruzzo	2.37	3.69	2.24
Basilicata	0.28	0.61	0.42
Calabria	0.41	0.54	0.14
Campania	4.51	4.53	2.80
Emilia-Romagna	12.09	12.93	15.24
Friuli Venezia-Giulia	2.74	3.24	2.94
Lazio	2.52	2.66	2.80
Liguria	0.98	1.03	0.56
Lombardia	26.99	25.30	31.47
Marche	4.64	4.18	4.48
Molise	0.26	0.42	0.28
Piemonte	9.19	9.24	8.95
Puglia	3.46	3.36	1.82
Sardegna	0.88	1.03	0.98
Sicilia	2.24	2.17	2.24
Toscana	11.90	9.22	9.51
Trentino Alto Adige	1.07	1.40	1.12
Umbria	1.56	1.52	1.26
Valle d'Aosta	0.13	0.16	0.00
Veneto	11.79	12.79	10.77

Table 3 – Sample distribution by industry

Industry	%
Food, beverages and tobacco	8.11
Textile	12.31
Leather	4.06
Wood	3.64
Paper, publishing, printing	5.59
Coke, petroleum, nuclear fuel	0.70
Chemicals	4.06
Rubber, plastics	6.85
Non-metallic mineral products	5.87
Metal products	15.24
Machinery, equipment	16,36
Electrical and optical equipment	9.09
Transport equipment	1.82
N.e.c., furniture	6.29
Total	**100.00**

The variables measuring spatial agglomeration come from the Census of Industry and Services conducted by ISTAT in 1991. We draw particularly on census information on employment and population density at the Administrative Provinces level.

Tables 4, 5 and 6 present some descriptive evidence on our main variables. Table 4 shows that exporting firms, on average, are larger, more productive, more likely to introduce new products and/or processes, more specialized compared to domestic firms, but also located in denser areas.

Table 4 – Mean characteristics of exporting firms (2003)

	Yes	No
Innovation (2003)	%	%
- Product or process	78.65	21.35
- Product	82.59	17.41
- Process	74.92	25.08
- Intensity (mean share 2003)	12.035	7.777
Productivity (mean 2003)	Mean value	Mean value
- Y/L	4.096	3.885
- Growth rate 2001-2003	-0.027	-0.032
- TFP	4.685	4.475
- Growth rate 2001-2003	-0.027	-0.029
Agglomeration (mean 1991, natural logarithms)*	Mean value	Mean value
- Specialization	0.187	0.113
- Related Variety	1.753	1.710
- Unrelated Variety	2.931	2.931
- Density	0.788	0.580
Size (mean employees 2003)	109	73

Notes: * for a description of spatial agglomeration variables see Section 3.2.1.

Table 5 shows that firms introducing new products and/or new processes tend to be more willing to export, slightly more productive (both in terms of labour productivity and in terms of TFP), more specialized and located in areas characterized by a relatively high related variety.

Table 5 – Mean characteristics of innovative firms (2003)

	Yes	No
Export (% 2003)	66.60	33.40
- Intensity (mean share 2003)	31.5	20.9
Productivity (mean 2003)	Mean value	Mean value
- Y/L	4.040	4.028
- Growth rate 2001-2003	-0.047	-0.000
- TFP	4.646	4.591
- Growth rate 2001-2003	-0.044	-0.004
Agglomeration (1991, natural logarithms)*	Mean value	Mean value
- Specialization	0.183	0.141
- Related Variety	1.753	1.721
- Unrelated Variety	2.904	2.952
- Density	0.713	0.739
Size (mean employees 2003)	126	58

Notes: * for a description of spatial agglomeration variables see Section 3.2.1.

Table 6 presents details on Italian firms' productivity levels in year 2003. It can be seen that the most efficient firms are more present in foreign markets, are more innovative and more concentrated in specialized clusters. Also, productivity level increases with firm size, and productivity growth seems to be less negative for medium-sized firms.

Table 6 – Productivity by export, innovation, agglomeration and size

	Ln Y/L 2003	TFP 2003
Export 2003	4.096	4.685
Domestic	3.885	4.475
Innovative 2003	4.040	4.646
Non innovative	4.028	4.591
- Product innovation	4.057	4.614
- No product innovation	4.018	4.632
- Process innovation	4.038	4.671
- No process innovation	4.033	4.591
Localization (above average)	4.039	4.711
Localization (below average)	4.031	4.538
Related variety (above average)	4.060	4.531
Related variety (below average)	4.014	4.701
Unrelated variety (above average)	4.045	4.618
Unrelated variety (below average)	4.022	4.632
Density (above average)	3.968	4.558
Density (below average)	4.045	4.634
Small firms (11-50)	3.973	4.448
Medium (51-250)	4.104	4.843
Large (> 250)	4.354	5.469

3.2. The modelling strategy

To model the structural relationships among research, innovation, productivity and export, we specify and estimate a four equation recursive system which constitutes a modified version of the CDM model.

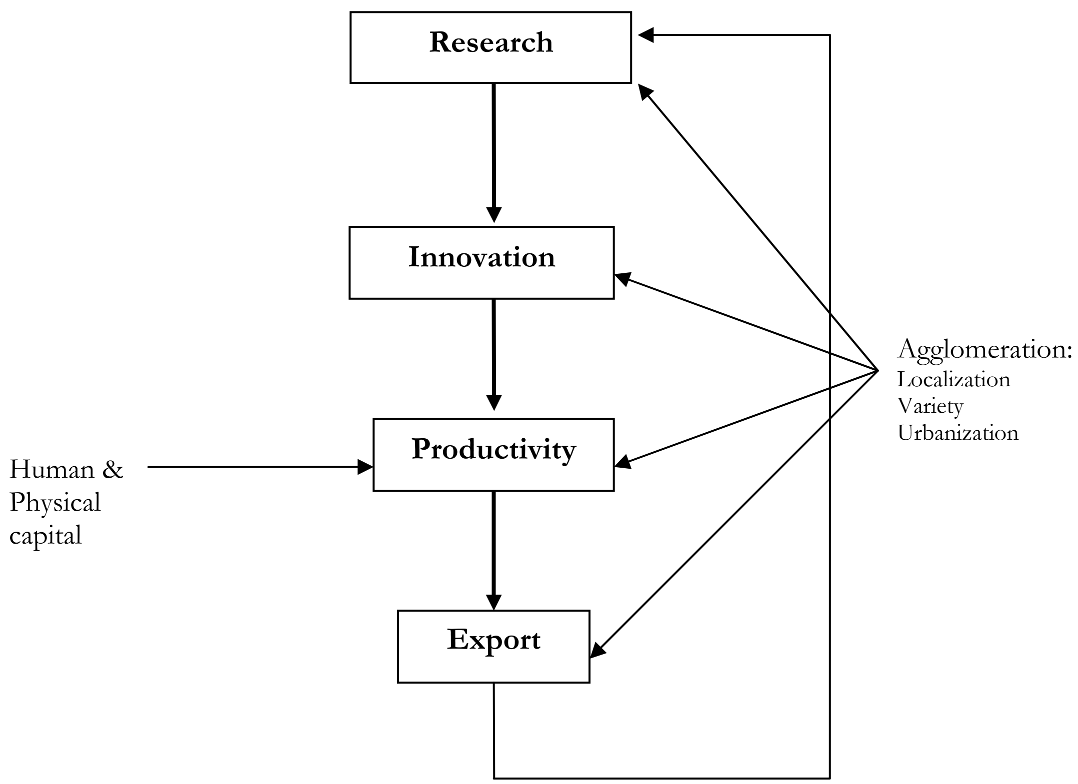
As already mentioned we extend this model in two ways. First, we introduce a new equation which should capture the empirical links between productivity and firms' export performance. Second, we empirically test for the effect of different forms of agglomeration economies in each stage, introducing measures of local knowledge spillovers: (i) localization economies, arising from the spatial concentration of firms in the same industry; (ii) Jacobs' externalities, spurred by the variety and diversity of geographically proximate industries, and capturing knowledge spillovers from the cross-fertilization of ideas from firms operating in related or unrelated sectors; and (iii) urbanization economies, which measure mainly information spillovers as local public goods, external to both firm and industry, and related to the size of the market and the density of the urban area in which the firm is located.

Note that although we do not rely on panel data, we avoid the problem of simultaneity by measuring all the explanatory variables in each equation three years before the period of the dependent variable.

Our model is depicted in Figure 1. It consists of four equations, one for research, one for innovation, one for total factor productivity, and one for export behaviour. The idea is that research capital is an input that affects the creation of new products/processes, which, in turn, affects firm's TFP level together with human and physical capital. Finally, TFP positively affects export behaviour by reducing the fixed costs associated with access to foreign markets.

All the above relations are assumed to be affected also by spatial agglomeration externalities, stemming from geographical concentration, variety and urbanization.

Figure 1 – The structure of the model



3.2.1. The research equation

The first equation in the model concerns firms' research intensity. Since our dataset includes firms that are not involved in research activities, we rely on a two-stage Heckman (1976, 1979) selection model in which we account first for the fact that the firm invested in R&D in 2003, and second we estimate the determinants of R&D intensity. Operationally, we assume that there is a latent variable r^* for firm i given by:

[1] $$r_i^* = x_{0i}\beta_0 + \varepsilon_{0i}$$

where x_{0i} is the set of explanatory variables, β_0 is the corresponding vector of the coefficients, ε_0 is the error term and r^* is the latent variable that reflects the criterion for the decision to engage in R&D: for example, the corresponding expected present value of profits. In this case, we observe that the firm invests in R&D if the expected profits are positive or larger than the industry-specific threshold (as in our case since we include a constant term and a set of industry dummies in every equation). In our sample of 715 firms, 49.4% are engaged in R&D compared to 50.6% of firms that are not.
Research intensity r is given by equation [2]:

[2] $$r_i = x_{1i}\beta_1 + \varepsilon_{1i}$$

where r is the 2003 real observed R&D investment per employee (in natural logarithms), x_{1i} is the vector of the explanatory variables, β_1 is the corresponding vector of coefficients and ε_1 is the error term. In estimating the Heckman two-stage model, we assume that the joint distribution of ε_0 and ε_1 is normal, with zero mean and constant variance-covariance matrix. In order to provide more robust estimates, we include an exclusion restriction in the first-stage selection equation.
Among the explanatory variables, we include:[4] (i) firm market share, computed as firm i sales over average sector sales; (ii) a set of 13 industry-specific dummies; (iii) age (measured up to year 1998); (iv) previous investment in R&D (measured up to year 2000); (v) a dummy variable capturing firm engagement in export in 2000[5]; (vi) a dummy variable equal to 1 if the firm benefited from tax incentives in the period 1998-2000 (for research and technological innovation); (vii) an exclusion restriction based on whether the firm was part of a R&D consortium in the period 1998-2000. This last variable is thought to be correlated with the probability of engagement in R&D, but not necessarily with R&D intensity.
Finally, following the literature on spatial agglomeration economies (Glaeser *et al.*, 1992; Cainelli and Leoncini, 1999; Cingano and Schivardi, 2003; Frenken *et al.*, 2007; Boschma and Iammarino, 2009) we include in this and the following equations: (i) a variable measuring local specialization; (ii) two variables measuring Jacobs externalities

[4] Unfortunately, our dataset does not include direct information on demand-pull or technology-push variables. Therefore, we deviate slightly from Crèpon *et al.*, (1998), although we do include firm size and sectoral specialization.
[5] In the absence of specific variable, we include market share and previous export activity in order to capture demand-pull factors (at national and international levels), while previous R&D expenditure is used as a proxy for science-push factors and technological opportunities. We use market share as a proxy for firm size.

through related and unrelated variety; (iii) a variable measuring urbanization economies at the Province level.
The first variable captures localization economies, or MAR externalities, i.e. the idea that specialized locations may benefit from within-industry knowledge spillovers coming from the spatial concentration of firms in the same industry. In line with the literature, we measure MAR externalities using the specialization index of sector *s* located in province *p* is computed as follows:

$$\text{Spec}_{s,p} = \frac{\dfrac{l_{s,p}}{l_p}}{\dfrac{l_{s,IT}}{l_{IT}}}$$

where $l_{s,p}$ denotes employment in industry *s* in Province *p*, l_p is total manufacturing employment in Province *k*, $l_{s,IT}$ is employment in industry *s* in Italy and finally l_{IT} is total manufacturing employment in Italy.
The second set of variables measures the positive externalities induced by the diversity of local economic activities outside sector *s* as a result of the cross-fertilization of ideas (Jacobs externalities) from related and unrelated sectors. In the former case, following Frenken *et al.*, (2007), we restrict attention to sectors located in province *p* but related to sector *s*. This allows us to calculate an index of *related variety* given by the 5-digit employment share within a 2-digit sector, and thus measuring the level of entropy within each 2-digit sector:[6]

$$\text{Relvar} = \sum_{g=1}^{G} P_g \left(\frac{1}{H_g} \right)$$

where H_g is the inverse of an Herfindahl concentration index calculated at the 5-digit level within each 2-digit level, and P_g is the share of the 2-digit sector *g*.
To measure unrelated variety, we use a standard measure of product diversification in each of the *N* available Italian provinces based simply on the inverse of an Herfindahl concentration index calculated at the 3-digit level. The value of this indicator increases, the more diversified is the productive structure of a Province. This variable is computed as follows:

$$\text{Variety} = \frac{1}{\sum_{i=1}^{N} p_i^2}$$

where p_i denotes the employment share of the 3-digit sector *i*.
Finally, the third variable measures urbanization economies by population density (at each Province level), computed as the number of local units per km^2 of the Province area:

$$\text{Density} = \frac{LU_P}{Area_P}$$

[6] To avoid problems of simultaneity with respect to both the dependent and the other explanatory variables, we calculate our agglomeration variables based on 1991 Census data.

This variable captures knowledge spillovers stemming from the concentration of many different economic activities irrespective of sectoral composition. Moreover, this variable is related to the size of the agglomeration and the importance of collective equipment, facilities, and information as well as to the size of the local (labour and final goods) market.

3.2.2. The innovation equation

The second equation in our extended model is an innovation production function which estimates the drivers of innovation output. Innovation output is measured first as the propensity to create a new product or a new process (*Innovation*). Since we deal with a binary variable, we estimate a Probit model of the following type:

[3] $$\Pr(Innovation_i = 1 \mid X = x_i) = \Phi(\alpha_R \hat{r} + x'_{2i}\beta_2 + \varepsilon_{2i})$$

where *Innovation* is the variable underlying the choice to innovate, x_2 is a set of explanatory variables, β_2 is the related vector of coefficients and ε_2 is the error term, distributed according to a standard normal distribution with zero mean and unit variance.
The set of explanatory variables includes absorptive capacity factors and knowledge inputs (Cohen and Levin, 1991). Among the former, we include firm market share, a set of industry-specific dummies, investment intensity (computed as the sum of 1998-2000 real investments in new machinery and equipment, in logs) and spatial agglomeration variables. Including spatial agglomeration in equation [3] allows us to test whether the effect of these variables on innovation output passes completely through the intensity of research or whether there are constant returns to agglomeration.
Knowledge inputs includes previous innovation activity (given by a dummy equal to 1 if the firm created a new product or process in the period 1998-2000) and the predicted value of the research equation. This accounts for persistence of innovation activity and innovation inputs, i.e. R&D intensity which, in turn, is explained by variables measured three years earlier.
In addition, we define innovation output in terms of the probability of a new product or a new process being introduced in the three years 2001-2003,[7] with the aim of disentangling the role of local externalities in different types of innovation.
We separately estimate a bivariate Probit model in which we assume the presence of an unobserved propensity latent variable I^* proportional to the unobserved level of expected profits from each type of innovation (j = product, process).
This latent profit is given by:

[4a] $$I_j^* = \alpha_r \hat{r}_j + x_{3j}\beta_{3j} + \varepsilon_{3j}$$

which can be mapped to an observable binary discrete variable I_j indicating whether a firms introduces (or not) one of the two types of innovations:

[4b] $I_j = 1$ if $I_j^* > 0$ and $I_j = 0$ if $I_j^* \leq 0$ (j = product, process).

The choices to create a new product or a new process are jointly modelled as a system of correlated equations, i.e. a system of equations with correlated error terms, which are

[7] Unfortunately we do not have information on the number of new products or processes developed.

supposed to be jointly distributed according to a multivariate normal distribution with variance-covariance matrix Σ given by:

[4c] $$\Sigma = \begin{pmatrix} 1 & \rho_{12} \\ \rho_{12} & 1 \end{pmatrix}$$

in which ρ_{12} represents the correlation coefficient between the two error terms.[8]

3.2.3. The productivity equation

After estimating R&D and innovation, we define our productivity equation by estimating a Cobb-Douglas production function with physical and human capital, local externalities and innovation output as the main determinants:

[5] $$y_i = \alpha_I I_i * + x_{4i}\beta_4 + \varepsilon_{4i}$$

where y_i is the productivity variable, measured, respectively, as the natural logarithm of value added per employee (in year 2003) and by TFP (at 2003) estimated through the semi-parametric method provided by Levinsohn and Petrin (2003); x_{4i} is the set of explanatory variables, β_4 is the related vector of coefficients, and ε_4 is the error term about we do not make any *a priori* assumptions.
Among x_{4i} we include: (i) firm size; (ii) physical capital per employee (as the net book value of physical capital adjusted for inflation); (iii) human capital (i.e. the share of managers and executives); (iv) firm organization, as given by two dummies capturing membership to a business group or a consortium in 1998-2000; and, again, (v) spatial agglomeration. Coefficient α_I is now the elasticity of productivity with respect to innovation output.

3.2.4. The export equation

Finally, we estimate the equation for Italian firms' export behaviour in year 2003. This is measured in three ways: (i) first, we simply estimate a Probit model for the propensity to export in 2001-2003; (ii) then, we estimate a Tobit model for the share of 2003 export sales; (iiv) finally, we estimate an ordered Probit model for the number of macro-areas into which firms exported goods in 2003.
The propensity to export is estimates according to equation [6]:

[6] $$\Pr(export_i = 1 \mid X = x_i) = \Phi(\alpha_Y \hat{y}_i + x_{5i}\beta_5 + \varepsilon_{5i})$$

where x_{5i} is a set of explanatory variables, β_5 is the corresponding vector of coefficients and ε_5 is the error term, which we assume to have the usual statistical properties. The coefficient α_y reflects the impact of (predicted) productivity (TFP) on the decision to export in 2003.

[8] A correlation coefficient equal to zero implies the error terms are distributed according to the standard normal distribution, so that a univariate Probit specification can be used for both estimations. However, since our two dependent variables (product and process innovation) are significantly correlated (with a ρ equal to -0.4), we face two non-zero off-diagonal elements of Σ, which means that we need a multivariate probit specification in order to account for correlations across the disturbances of the two latent equations, which, in turn, embodies unobserved characteristics for the same firm.

Relying on the same set of explanatory variables, we additionally focus on export intensity, computed as the share of total sales coming from the sale of goods in foreign markets. Since this variable is left and right censored to 0 and 1 respectively, we estimate a Tobit model in which we assume that such a dependent variable is continuous. The coefficient α_y, in this case, represents the marginal impact of predicted productivity on firms international competitiveness, i.e. on the profitability of export.
Finally, we provide a non-monetary measure of export intensity. Since export sales may reflect not only the real competitiveness of firms, but also global demand conditions (Malmberg *et al.*, 2000), we measure export intensity also by counting the number of macro areas[9] that the firm has served through its exporting activity. We define an ordered variable that equals 0 for purely domestic firms, 1, 2 and 3 for firms exporting in one, two and three macro regions respectively, and 4 for firms serving more than three areas. We estimate export intensity with an ordered Probit model in which we assume the error term to be normally distributed with zero mean and constant variance.
Following the recent theoretical and empirical literature on the determinants of export performance (Bernard and Jensen, 1999, 2004; Ferragina and Quintieri, 2001; Sterlacchini, 2001; Melitz, 2003), we include in our explanatory variables: (i) market share; (ii) sectoral specialization; (iii) age; (iv) membership of a business group or consortium as a measure of firm organization; (v) investment in information and communication technologies (ICT) during the three years 1998-2000 (dummy), and (vi) the predicted level of TFP.

3.2.5. The full model

The full model is given by a set of five equations, two for R&D, one for innovation output, one for productivity and one for export. We summarize these equations as follows.
Research:

$$[7] \qquad r_i^* = x_{0i}\beta_0 + \varepsilon_{0i}$$

$$[8] \qquad r_i = x_{1i}\beta_1 + \varepsilon_{1i},$$

innovation:

$$[10] \qquad \Pr(Innovation_i = 1 \mid X = x_i) = \Phi(\alpha_R \hat{r} + x'_{2i}\beta_2 + \varepsilon_{2i})$$

productivity (TFP):

$$[11] \qquad y_i = \alpha_I I_i^* + x_{4i}\beta_4 + \varepsilon_{4i},$$

export

[9] These macro areas are: (1) EU-15 countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Luxemburg, the Netherlands, United Kingdom, Spain and Sweden); (2) countries that joined the EU in 2004 (Cyprus, Estonia, Latvia, Malta, Poland, Cech Republic, Slovakia, Slovenia, Hungary); (3) Russia, Turkey and other European countries; (4) Africa; (5) Asia (excluding China); (6) China; (7) United States, Canada and Mexico; (8) Centre and South America; (9) Australia.

$$[12] \qquad \Pr(export_i = 1 \mid X = x_i) = \Phi(\alpha_Y \hat{y}_i + x_{5i}\beta_5 + \varepsilon_{5i}) .$$

3.3. The empirical findings

Tables 7 to 10d report the main results of our analysis. Table 7 refers to the first two equations for R&D capital; Tables 8a and 8b refer to the innovation output functions; Tables 9a and 9b refer to the TFP estimations and Tables 10a-10d refer to exporting.

Table 7 shows that the intensity of R&D capital investments increases with both demand-pull and technology-push factors, or with firm's market share and previous investment in R&D. R&D intensity is driven by firm experience and tax incentives but even more by the strong impact of spatial agglomeration: in particular, related variety and urbanization play a highly statistically significant and positive role in increasing the intensity of R&D, once the decision to invest in this activity is taken. Unrelated variety, in contrast, decreases R&D intensity.

The positive relationship between R&D and related variety can be viewed from two perspectives. On the one hand, following Frenken *et al.* (2007), R&D may benefit more from local knowledge spillovers from related sectors, i.e., from new ideas derived from different, complementary, knowledge sources. On the other hand, unrelated variety may be associated with increased knowledge dispersion and it may decrease the expected returns to R&D, thus lowering levels of R&D investment.

The positive effect of urbanization economies may reflect the fact that large agglomerations, or large cities, may host a variety of activities linked to R&D universities, research laboratories, advanced services, local credit, trade associations and other knowledge-based organizations. According to Frenken *et al.* (2007, p. 687), "the diverse industry mix in an urbanized locality also improves the opportunities to interact, copy, modify, and recombine ideas, practices and technologies across industries giving rise to Jacobs externalities".

Table 7 – Research capital

Variables	$\ln R\&D/L_{2003}$ Coeff. (bootstrapped s.e.)	Selection = $R\&D_{2003}$ Coeff. (bootstrapped s.e.)
Age	0.3706*	-0.0148
	(0.1849)	(0.0700)
Market $share_{2000}$	0.4619**	0.2445***
	(0.1558)	(0.0562)
$\ln R\&D_{2000}$	0.2745**	0.1903***
	(0.1040)	(0.0181)
$Export_{2000}$	0.7704	0.2659*
	(0.5713)	(0.1345)
Tax $incentives_{1998\text{-}2000}$	0.8051*	0.0114
	(0.3648)	(0.1366)
Specialization	0.1346	-0.0207
	(0.2198)	(0.0842)
Related Variety	3.1144**	0.4778
	(1.0385)	(0.3979)
Unrelated Variety	-1.2602**	-0.1234
	(0.4375)	(0.1926)
Urbanization	0.1544*	0.0359
	(0.0626)	(0.0287)
R&D $Consortium_{2000}$	…	4.7160***
		(0.2927)

N. Obs.	715
Uncensored Obs.	353
Mills Lambda	3.929***
Wald χ^2 (21)	154.36 ($p < 0.000$)

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Estimations include 13 industry-specific dummies.

Table 8a shows that the impact of spatial agglomeration externalities is concentrated in the input phases of the innovation process. The propensity to innovate, in line with the Schumpeterian view of innovation, is affected mainly by R&D and firm size, i.e. market share.

When we investigate product and process innovation separately, we find that, while the former is driven more by past experience and R&D investments, and less by size, the latter depends much more on market share and investment in new equipment. This confirms the results in the literature on innovation in Italy (Parisi *et al.*, 2006), where process innovation is shown to favour large firms and is embodied in new machinery and capital goods.

In addition, we find a significant role of unrelated variety: being located in a highly diversified productive structure increases the probability of a process innovation. If the introduction of a process innovation reflects capital-embodied technological change, then we can reasonably expect that different capital goods may come from firms belonging to different industries. Therefore, although on the one hand unrelated variety may hinder R&D investment, on the other, it may favour process innovation by increasing the pool of firms providing capital goods.

Table 8a – Innovation output

	Innovation		Product	Process
Variables	Probit	dy/dx	Bivariate probit	Bivariate probit
Age	0.0682	0.025	-0.0174	0.0789
	(0.0700)	(0.026)	(0.0708)	(0.0722)
Market share$_{2000}$	0.1212*	0.046*	0.0388	0.1054*
	(0.0514)	(0.019)	(0.0478)	(0.0474)
Investment$_{2000}$	0.0050	0.002	-0.0080	0.0217
	(0.0123)	(0.005)	(0.0129)	(0.0125)
Innovation$_{98\text{-}00}$	0.1394	0.053	0.2807*	0.1853
	(0.1110)	(0.042)	(0.1090)	(0.1086)
Specialization	0.0172	0.007	-0.0692	0.0404
	(0.0699)	(0.026)	(0.0683)	(0.0700)
Related Variety	-0.3056	-0.116	-0.3854	-0.4934
	(0.3284)	(0.124)	(0.3206)	(0.3263)
Unrelated Var.	0.1898	0.072	0.0374	0.3810*
	(0.1632)	(0.062)	(0.1604)	(0.1664)
Urbanization	-0.0018	-0.000	0.0160	-0.0118
	(0.0266)	(0.010)	(0.0257)	(0.0261)
R&D (predicted)	0.1789***	0.068***	0.1894***	0.1222***
	(0.0328)	(0.012)	(0.0316)	(0.0316)
N. Obs.	715	715	715	
PseudoR^2	0.1256			
Pearson χ^2 (693)	709 ($p = 0.331$)			
Log Likelihood			-848.65	
Rho			0.369***	

Notes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Cluster-robust standard errors in parentheses. Estimations include 13 industry-specific dummies. Pearson chi-squared statistics refers to Hosmer and Lemeshow goodness of fit test.

Table 8b – Marginal effects after bivariate probit estimation

	Product		Process	
Variables	Marginal	Joint	Marginal	Joint
Age	-0.007	-0.018	0.031	0.019
Market share$_{2000}$	0.015	-0.010	0.041*	0.015
Investment$_{2000}$	-0.003	-0.006	0.008*	0.006*
Innovation$_{98\text{-}00}$	0.110*	0.030	0.072	-0.009
Specialization	-0.027	-0.023	0.016	0.020
Related Variety	-0.151	0.002	-1.192	-0.038
Unrelated Var.	0.015	-0.060	0.148*	0.072*
Urbanization	0.006	0.006	-0.005	-0.005
R&D (predicted)	0.075***	0.021**	0.047***	-0.006

Another interesting result emerges from the productivity estimates (Tables 9a and 9b). While, as expected, innovation output contributes directly to TFP (as in Crépon *et al.*, 1998), this impact is statistically significant at the 5% level. Complementary to innovation, size and localization externalities strongly contribute to increasing productivity, while variety does not play role in either TFP or labour productivity. This result is in line with the literature on the sources of local productivity growth (Cingano and Schivardi, 2003); however, our structural model allows us to identify a positive role also for variety-based externalities, an effect that is not directly captured in reduced form models, since it is filtered by the impact of R&D on innovation, and innovation on productivity.

Table 9b shows that the impact of innovation on TFP is due to product rather than process innovation. In this respect, we can speculate that related rather than unrelated variety, impacts indirectly on productivity.

Table 9a – Productivity

	(1) TFP	(2) Y/L
Medium	0.3622	0.0762
	(0.2062)	(0.0506)
Large	1.2787**	0.2224*
	(0.4162)	(0.0952)
Group2000	0.0016	0.1470*
	(0.2248)	(0.0719)
Consortium2000	0.5565*	0.0952
	(0.2616)	(0.0679)
Human Capital2000	0.1161	0.0581
	(0.1110)	(0.0304)
Physical Capital2000	0.2631***	0.0509*
	(0.0791)	(0.0232)
Specialization	0.3262***	0.0330*
	(0.0942)	(0.0258)
Related Variety	-0.7293	0.2059
	(0.4620)	(0.1101)
Unrelated Variety	0.1303	-0.0788
	(0.2095)	(0.0626)
Urbanization	-0.0517	-0.0085
	(0.0348)	(0.0085)
Innovation	0.3666*	0.1037**
	(0.1570)	(0.0394)

N. Obs.	715	715
R^2	0.111	0.100
F (11, 714)	6.1965	7.8056

Notes: cluster-robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 9b – Product innovation, process innovation and TFP

	(1)	(2)
Medium	0.3731	0.5582**
	(0.2031)	(0.2024)
Large	1.3460**	1.6135***
	(0.4106)	(0.4042)
Group2000	-0.0141	0.0455
	(0.2242)	(0.2233)
Consortium2000	0.5643*	0.6031*
	(0.2598)	(0.2672)
Human Capital2000	0.1193	0.1035
	(0.1111)	(0.1106)
Physical Capital2000	0.2936***	0.2949***
	(0.0797)	(0.0796)
Specialization	0.3561***	0.3426***
	(0.0939)	(0.0958)
Related Variety	-0.7856	-0.5309
	(0.4612)	(0.4570)
Unrelated Variety	0.2270	0.1196
	(0.2120)	(0.2171)
Urbanization	-0.0572	-0.0462
	(0.0350)	(0.0343)
Product Innovation	1.1297**	…
	(0.3872)	
Process Innovation	…	-0.2038
		(0.5516)
N. Obs.	715	715
R^2	0.1150	0.1049
F (11, 714)	6.6708	6.0637

Finally, we test the role of TFP on export performance through a set of three specifications. First, we focus on the probability to export. Table 10a shows that younger, more productive and more "urbanized" firms are more willing to enter foreign markets. Therefore, in addition to TFP, we find that firms use other means to cope with the fixed costs associated with internationalization: the density of the urban structure. As before, the local availability of advanced services, qualified skills, infrastructures, universities, information sources and so on may help firms to reduce the sunk costs associated with the sale of goods at the international level.
These results are confirmed when we measure export intensity through export sales (Table 10b) and the number of macro-regions (Tables 10c and 10d). The higher the intensity of export, the higher the complementary role of TFP and urbanization economies.

Table 10a – Propensity to export, 2003 (marginal effects at the mean)

Variables	(1)	(2)	(3)
Age	-0.057*	-0.054*	-0.040
	(0.027)	(0.027)	(0.027)
Market share	0.044	0.046	0.087***
	(0.026)	(0.025)	(0.024)
Group	-0.108	-0.108	-0.084
	(0.059)	(0.059)	(0.059)
Consortium	-0.000	0.000	0.079
	(0.073)	(0.072)	(0.066)
ICT	0.030	0.030	0.035
	(0.048)	(0.048)	(0.048)
Specialization	-0.016	-0.016	0.035
	(0.032)	(0.030)	(0.031)
Related Variety	0.222	0.233	0.116
	(0.121)	(0.121)	(0.119)
Unrelated Variety	-0.057	-0.062	-0.030
	(0.059)	(0.059)	(0.059)
Urbanization	0.031**	0.031**	0.024*
	(0.010)	(0.010)	(0.010)
TFP	0.151**	…	…
	(0.057)		
TFP_product	…	0.149**	…
		(0.052)	
TFP_process	…	…	0.006
			(0.051)
N. Obs.	715	715	715
Pseudo R^2	0.1541		
Log Likelihood	-397.3614	-396.7140	-400.8225
Wald χ^2 (22)	114.82 (p<0.000)		

Cluster-robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 10b – Export intensity: share of export sales, 2003 (marginal effects after Tobit)

Variables	(1)	(2)	(3)
Age	-0.040*	-0.037	-0.029
	(0.020)	(0.020)	(0.020)
Market share	0.049*	0.050*	0.085***
	(0.022)	(0.021)	(0.020)
Group	-0.065	-0.064	-0.042
	(0.043)	(0.043)	(0.043)
Consortium	0.002	0.002	0.066
	(0.051)	(0.049)	(0.050)
ICT	0.024	0.023	0.028
	(0.041)	(0.041)	(0.041)
Specialization	-0.001	-0.000	0.037
	(0.026)	(0.025)	(0.026)
Related Variety	0.151	0.158	0.078
	(0.097)	(0.097)	(0.097)
Unrelated Variety	-0.054	-0.057	-0.032
	(0.050)	(0.050)	(0.050)
Urbanization	0.023**	0.023**	0.017*
	(0.007)	(0.007)	(0.007)
TFP	0.096*	…	…
	(0.044)		

TFP_product	…	0.095*	…
		(0.041)	
TFP_process	…	…	-0.016
			(0.040)
N. Obs.	715	715	715
Uncensored Obs.	450	450	450
Pseudo R^2	0.1887	0.1896	0.1839
Log Likelihood	-390.18	- 389.75	-400.8225

Cluster-robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 10c – Export intensity: number of macro-regions (ordered Probit coefficients)

	(1)	(2)	(3)
Age	-0.0142	-0.0087	0.0139
	(0.0587)	(0.0582)	(0.0581)
Market share	0.2000***	0.2007***	0.2794***
	(0.0518)	(0.0497)	(0.0474)
Group	-0.1221	-0.1233	-0.0803
	(0.1195)	(0.1194)	(0.1205)
ICT	0.2027	0.2024	0.2135*
	(0.1065)	(0.1064)	(0.1063)
Specialization	-0.0254	-0.0265	0.0611
	(0.0686)	(0.0671)	(0.0664)
Related Variety	0.4975	0.5215	0.2999
	(0.2705)	(0.2710)	(0.2667)
Unrelated Variety	-0.2599*	-0.2704*	-0.2080
	(0.1319)	(0.1322)	(0.1321)
Urbanization	0.0804***	0.0801***	0.0685**
	(0.0222)	(0.0221)	(0.0222)
TFP	0.2630*	…	…
	(0.1092)		
TFP_product	…	0.2666**	…
		(0.1010)	
TFP_process	…	…	0.0113
			(0.1008)
N. Obs.	715	715	715
Log Likelihood	-1025.35	-1024.76	-1028.24
Pseudo R^2	0.0874	0.0879	0.0848
LR test	66.30 (p=0.364)	66.57 (p=0.355)	67.12 (p=0.338)

Cluster-robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. LR test refers to approximate likelihood-ratio test for equality of coefficients.

Table 10d – Marginal effects of selected variables after ordered probit estimation

N. of countries	1	2	3	4
Market share	-0.015**	0.005*	0.018***	0.056***
ICT(*)	-0.013*	0.008	0.019	0.054*
Specialization	0.002	-0.001	-0.002	-0.070
Related Variety	-0.038	0.014	0.045	0.139
Unrelated Variety	0.020	-0.007	-0.002	-0.073*
Urbanization	-0.006*	0.002*	0.007**	0.022**
TFP	-0.020*	0.007*	0.024*	0.073*
TFP_product	-0.020*	0.007*	0.024*	0.074**
TFP_process	-0.001	0.000	0.001	0.003

(*) dy/dx is for discrete change from 0 to 1.

4. Conclusions

Using a large sample of Italian manufacturing firms, we estimate a structural model of research, innovation, productivity and export performance augmented to take account of the role played by local externalities. In so doing, we combine three main bodies of the recent literature: (i) works concerned with the empirical determinants of innovative activities; (ii) studies of the role played by agglomeration economies as drivers of local productivity and (iii) research linking productivity, as the main source of firm heterogeneity, to export.

The model used in the paper, which is an "enlarged" version of the CDM model, comprises four main equations. The first identifies the factors underlying the intensity of R&D investments; the second links R&D capital to innovation output; the third focuses on TFP as determined by innovation; the fourth relates export performance to TFP. To avoid problems of simultaneity, in each equation we measure our dependent variables in year 2003, while the explanatory variables refer to the period 1998-2000.

Unlike some related studies, we include in our analysis a set of variables measuring local knowledge spillovers, i.e. localization, variety and urbanization economies. The first measure captures MAR externalities based on geographical agglomeration of firms belonging to the same industry; the second focuses on Jacob externalities and knowledge spillovers from the cross-fertilization of ideas among firms operating in related and unrelated industries. The third measure concerns agglomeration economies – mainly information spillovers as local public goods – external to both firms and industry, and is related to the size of the market and the density of the urban area in which the firm is located.

Our estimates show that agglomeration economies do play a role in shaping the relationship between innovation, productivity and export performance. In particular, we find that related variety and urbanization economies promote R&D and the generation of new ideas, while specialization affects the exploitation of innovation in terms of higher levels of TFP. Finally, urbanization economies – through the availability of large labour pools, intermediate goods and services and extensive knowledge spillovers from the interactions with many local agents and institutions – do positively affect both R&D and also the propensity to export and the relative export intensity.

One of the main contributions of this paper is that, unlike other studies in this area, we do not rely on a "reduced form" relationship, but, rather, we estimate a structural model in which we identify the forms of spatial agglomeration that affect innovation, productivity and export performance. In this sense, this approach can be seen as providing a better understanding of these relationships, opening the "black box" of the mechanisms that are at the basis of firms' competitive advantage.

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